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KNOWLEDGE-BASED CAPITAL IN LATIN AMERICA: THE LA KLEMS-BID PROJECT

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Knowledge-Based Capital in Latin America: The LA KLEMS-BID project

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Abstract

This paper presents the framework and methodology which will be applied to the LA KLEMS-BID database once it is released. It addresses the economic valuation of knowledge-based capital in ten Latin-American countries, namely Argentina, Brazil, Chile, Colombia, Costa Rica, El Salvador, Honduras, Mexico, Peru and Dominican Republic. It uses an alternative approach to measuring the knowledge intensity of economies to those based on the aggregation of industries according to selected indicators such as R&D expenditure or labor force skills. We follow an economic approach rooted in growth accounting methodology, determining the contribution of each individual factor (capital and labor) according to the prices of the services it provides. This methodology will be applied to ten Latin-American countries, the United States and Spain which are used as benchmarks. The analysis will cover the period 1995-2015

JEL classification: O33, O47

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1. Introduction

Knowledge economy is the term applied to describe an economy where a considerable share of production is based on accumulated knowledge. Despite this term being frequently used, there is no metric that accurately measures how much economic value stems from knowledge. The most widely-used approach classifies productive activities into several categories according to technological intensity, usually on the basis of R&D expenditure or high-skilled labor¹. Calculations are then made on the percentage that these activities represent in total employment or production.

There are three important limitations regarding these conventional measures of knowledge intensity. The first is that it focuses on the current creation of knowledge rather than how the productive system uses it, which is crucial to analyzing certain problems. The second is that it uses classifications of knowledge intensity in activities based on a single factor: R&D expenditure in the case of manufacturing, and human capital with higher education in services industries. Knowledge, however, is incorporated into production through various channels: qualified labor in general, some capital assets and intermediate inputs. The weight that each of these carries in industries is different, and, therefore, classifying activities based on a single criterion could bias the results. The third major limitation is that the incorporation of knowledge varies from one country to another within the same industry. The reality is that knowledge is (more or less) present in all industries and not only in those defined as high or medium technology in the usual classifications, which in turn have different degrees of knowledge intensity by country.

Other studies examine the knowledge economy through a set of indicators which includes several profiles of the presence of knowledge in productive activities. In some cases, synthetic indices of the development of knowledge —both in the economic system and society— are elaborated, including multiple variables which are aggregated according to statistical criteria or ad hoc weights. However, many of these indices are

¹ See, for example, the definition of KIS (Knowledge Intensive Services) and HTech (High Technology Manufacturing) or KIA classification (Knowledge Intensive Activities), which are used by Eurostat (2013). OECD (2015) uses these classifications as well. See also Tradecan (Trade Competitive Analysis of Nations) methodology, which was developed in 1990 by the Economic Commission for Latin America and the Caribbean (ECLAC).

usually partial² and have an ambiguous meaning, given that they are not derived from a metric based on clear definitions and evaluation criteria, nor on a precise structure of relationships between variables. In this sense, business accounting and the system of national accounts have advantages for the aggregation, which is based on the relative prices of goods or factors.

The paper will explore whether it is possible to assess the intensity with which knowledge is used –not its generation or creation– within economies by means of a methodology that is integrated into the conceptual schema, measurement criteria and information systems of national accounts. To answer this question, we can take two different approaches: the development of *knowledge satellite accounts*, and the development of *knowledge accounting*.

Regarding the first option, the complexity and data requirements of satellite accounts are considerable, given that they aspire to build an integrated system that quantifies all dimensions and elements present in the dynamics of a knowledge-based economy. Because of that, although some official statistics institutes have taken preliminary steps in developing such knowledge satellite accounts³, they are not available for the majority of countries.

The second alternative takes advantage of the important theoretical and empirical advances achieved in the measurement of physical and human capital⁴. We have chosen to go in this direction, proposing to measure the weight of knowledge in GDP by calculating the market value of a set of knowledge-based inputs which are incorporated in the production processes. The cornerstone of this approach is the analytical structure of modern *growth accounting*, which allows us to differentiate the value of various types of physical and human capital service inputs. This methodology was initially proposed by Pérez and Benages (2012) and applied to all the European countries included in the EU KLEMS database. Maudos et al. (2017) updated and expanded this methodology

² Some examples are the KEI and KAM indicators published by the World Bank (see Chen and Dahlman [2006] and World Bank [2008a, 2008b] for more details) or the Digital Economy and Society Index (DESI) developed by the European Commission (see more details at: https://ec.europa.eu/digital-single-market/en/desi). All of them take into account different economic and social dimensions to measure the development of the knowledge economy, but exclude some important areas, such as physical capital endowments, institutional characteristics of the labor markets, etc., which may be relevant.

³ See Haan and van Rooijen-Horsten (2003) and van Rooijen-Horsten et al. (2008).

⁴ See Jorgenson et al. (1987).

applying it to the Spanish regions for which KLEMS-type data is available. Mas, Hofman and Benages (2018) revised and extended it to a set of four Latin- American countries, and Mas, Hofman and Benages (2019) to the same four Latin-American countries, the United States, and five European countries (France, Germany, Italy, Spain, and the United Kingdom).

The proposed methodology can be applied today to those economies whose national accounts systems offer industry data on various types of labor and capital services and their corresponding compensation. Databases that allow these estimates to be carried out have been created and harmonized by projects developed within the framework of WORLD KLEMS, devoted to examining productivity and sources of economic growth⁵. In our case, we will make use of two recently released databases. The first is LA KLEMS (http://laklems.net/), which at present contains information for five Latin-American countries: Argentina, Brazil, Chile, Colombia, and Mexico, but is expected to release in brief data for Costa Rica, El Salvador, Honduras, Peru and Dominican Republic. From the recently updated version of EU KLEMS (http://euklems.net/) we can take the information for Spain, while the information for the United States will stem mainly from the USA KLEMS database (available at http://www.worldklems.net/data.htm), although, when necessary, information from BLS (Bureau of Labor Statistics) and BEA (Bureau of Economic Analysis) will also be used to update and supplement this database.

There are many questions we are interested in answering in this study. Is the value added generated by the factors of production incorporating knowledge high enough to speak of *knowledge economies*? What differences can we observe in the weight of knowledge among industries and among countries? What is the time evolution of knowledge intensity by industry and by economy? Do activities and countries converge in knowledge intensity?

2. Calculating knowledge intensity: methodological approach

The most widely-used approach for measuring knowledge intensity in economies is based on classifying manufacturing industries according to technology intensity— measured by the weight of R&D expenditure in relation to GDP—and services industries

⁵ See http://www.worldklems.net/.

according to the use of human capital—measured by the percentage of staff with higher education⁶. The first one, the weight of R&D, responds better to the objective of analyzing the intensity in which knowledge is created rather than how much knowledge is used. In fact, the classification of manufacturing according to technological intensity was conceived for another purpose: to assess the origin of exogenous technological progress and its role in growth and competitiveness. The focus on R&D activities is justified since technology-intensive companies and industries show a high innovative and commercial dynamism and are especially productive⁷.

It is clear that R&D activities play a key role in generating knowledge. This knowledge is incorporated in the capital assets used in the production process. Machinery and other capital goods are the key vehicles for the use of knowledge. These capital goods are previously produced incorporating the knowledge used in their own production process, and are almost always intensive in human capital and in the use of other machinery. The same can be said of some intermediate products, although the degree in which they incorporate knowledge varies to a greater extent than in the case of machinery.

Since our objective is to measure the weight of knowledge used in current production, we should not concentrate solely on the discoveries of today but rather on all the knowledge accumulated in capital assets throughout time. It is not a question of *measuring knowledge* but rather which part of the economic value of production remunerates the knowledge accumulated in the used inputs.

The refinement provided by the concept of productive capital offers a greater precision for measuring capital services and allows us to approximate the accounting of knowledge incorporated in the capital stock. Other analytical and statistical improvements in the methodology for measuring assets and their productive services are a consequence of a greater accuracy in aggregation procedures, using Tornqvist indices⁸. On account of these developments, an improved analysis is now available using sources of growth as well as key variables to estimate the value of production of assets incorporating knowledge. Developments currently underway extend the capital assets to take into account the contribution of intangible assets, many of which are also the

⁶ See OECD (2015) and Eurostat (2013).

⁷ See Hatzichoronoglou (1997).

⁸ See OECD (2001, 2009) and Jorgenson et al. (1987).

result of knowledge accumulated by companies and their organizations.⁹ A more accurate measurement of physical and human capital services better assesses the knowledge incorporated in the factors and reduces the weight of the Solow residual¹⁰. These advances in growth accounting illustrate that, when the contributions of productive factors are measured more precisely, incorporated knowledge is more relevant than total factor productivity when explaining improvements in labor productivity¹¹.

The methodological and statistical framework of advanced versions of *growth accounting* offers an appropriate scheme to build an *accounting* of the use of knowledge *in production*. We can consider that knowledge is incorporated into production through the use of different kinds of labor, capital, and intermediate inputs. However, to simplify the presentation of the methodology, and relate it to subsequent empirical findings, we only show the case in which the measurement of the product is gross domestic product (GDP) or gross value added (GVA), although the approach will be replicable in similar terms to the case of total production. Thus, we do not consider knowledge incorporated into intermediate inputs, but only content in primary inputs, labor and capital. Taking this into account, to assess the contribution of productive factors based on knowledge, first we have to identify which factors contain knowledge, measure the amount used in different activities, and value their services with appropriate prices.

From this point of view, knowledge intensity in an industry is defined as the value of the knowledge services used in relation to the value of its production. Thus, it can take any value in the interval [0,1]. Industries are therefore not classified into categories of greater or lesser intensity, avoiding the discontinuity caused by thresholds which arbitrarily separate some groups from others. However, certain arbitrariness is unavoidable when considering which assets include knowledge and which do not.

⁹ See Corrado et al. (2006), Marrano and Haskel (2006), Van Ark and Hulten (2007), Fukao et al. (2007), Marrano et al. (2007), Hulten (2008), Corrado et al. (2013, 2017). From our work's perspective, the services of intangible assets increase the value added generated but the income they yield could be allocated to the heart of the organizations, both to the owners of capital and labor. It is because these assets, by their nature, do not have an external market that determines their price. Therefore, their contribution can be considered to be accounted through the remuneration of other factors.

¹⁰ See Solow (1956, 1957).

¹¹ See Aravena et al. (2018), Coremberg and Pérez (2010), Oulton (2016) and Pérez and Benages (2017) on how a more accurate measurement of productive factors impacts total factor productivity.

One possibility is to take a very restrictive approach and include only ICT and intangible capital (on the asset side) and only workers with the highest level of tertiary education (on the labor side) as knowledge-contributing factors. This is the approach followed in Mas, Hofman and Benages (2018). Alternatively, we can also take a broader approach in which knowledge-based factors are understood to include not only high-skilled but also medium-skilled workers (higher and upper secondary education), and not only ICT but all types of machinery and equipment. Low-skilled workers and real estate capital are not considered to incorporate significant knowledge and so are excluded. This is the approach followed by Pérez and Benages (2012) and Mas, Hofman and Benages (2019). In this paper we will consider both approaches in order to assess the accuracy and sensitivity of the results obtained in each case.

As already mentioned, the knowledge intensity of an industry can take any value in the interval [0,1]. One of the implications of this is that, unlike the conventional approach, knowledge intensity in an industry is not constant over time or among countries. Another implication is that the knowledge intensity of an economy is obtained from the knowledge intensity in each of its industries, as well as from the weight of value added of each branch of activity in the aggregate GVA.

Assuming that there are *m* types of labor and *n* types of capital and some of these provide knowledge services and others do not, let L_{ij} be the amount of labor of type *i* used in sector *j*; K_{ij} the amount of capital of type *h* used in the same sector *j*; P_{ij}^{L} is the unitary wage paid for the labor of type *i* in sector *j*; and P_{hj}^{K} is the user cost of type *h* capital in sector *j*. Defining the value added in real terms produced by sector *j* as V_j and being P_j^V its price, the value added of sector *j* in nominal terms ($V_j P_j^V$) is distributed between the different inputs included in the production process so that,

$$V_j P_j^V = \sum_{i=1}^m L_{ij} * P_{ij}^L + \sum_{h=1}^n K_{hj} * P_{hj}^K$$
[1]

Let us assume that the price of the amount used for each type of labor depends on its productivity, and that the basis for differences in productivity is the human capital that each type contains. Under these hypotheses, wages can approximate the economic value of the amount of knowledge per unit of each type of labor. According to this criterion, we can consider that the type of labor that offers a lower wage (for workers with lower education levels) does not incorporate knowledge. While the other types of labor do incorporate knowledge, though at different rates according to the number of years or level of education. If we generalize to allow *f* type of low-skilled labor, the value of labor is decomposed into two parts, the second of which measures the value of human capital services:

$$\sum_{i=1}^{m} L_{ij} * P_{ij}^{L} = \sum_{i=1}^{f} L_{ij} * P_{ij}^{L} + \sum_{i=f+1}^{m} L_{ij} * P_{ij}^{L}$$
^[2]

Thus, the value of knowledge incorporated through labor (knowledge-intensive labor, KIL) would be given by:

$$KIL_{j} = \sum_{i=f+1}^{m} L_{ij} * P_{ij}^{L}$$
[3]

The unit value of productive services providing different kinds of labor that incorporate knowledge is not the same. For example, the production services of workers with higher education are more intensive in knowledge than in the case of workers with upper secondary education. By multiplying the amount of each type of labor by its wages, knowledge intensity can be accurately calculated when the wages are a reflection of this intensity. This criterion implies that the value of knowledge that qualified workers have does not depend on education per se but rather on their experience and how it is used by the productive system in general, which is reflected in their wages.

In terms of capital, we assume that the productivity of each asset is reflected in its user cost, which is taken into account in the calculation of the productive capital. The differences in the user cost have become more relevant due to the growing importance of ICT investment, which was a key driving force behind the disaggregation of assets and the distinction between net and productive capital¹².

The capital user cost has three components: the financial opportunity cost or rate of return, the depreciation rate resulting from the service life of the corresponding asset, and earnings or losses of capital arising from variations in its price. In the long-term, i.e., in the absence of price changes associated with the business cycle¹³, the component of the user cost that most differentiates certain assets from others is the depreciation rate, which depends on the average service life of the assets. The service life of machinery is shorter than housing or infrastructure, while that of ICT assets is shorter than the

¹² See OECD (2001, 2009).

¹³ See Schreyer (2009).

majority of machinery and transport equipment. The materials that make up the assets and, in particular, the complexity and vulnerability to obsolescence (i.e., the technology incorporated) make the economic life shorter (and depreciation faster). Assets that contain more knowledge tend to have a shorter economic life and a more intense depreciation, although there can be exceptions to this rule. In the language of capital theory, more depreciation means greater user cost that should be offset by a greater flow per unit of time of the asset's productive services, because otherwise the decision to invest in it would not be justified.

We assume that the content of knowledge in assets increases proportionately with its user cost. We use as a starting point the hypothesis that assets with a lower user cost do not incorporate knowledge in a significant way, while assets with a higher user cost do. Therefore, as aforementioned, we can assume that machinery and equipment do incorporate knowledge (although with the relative intensity reflected by their user cost, e.g., much higher in ICT assets) or we can follow a more restrictive view for capital which considers that only ICT and intangible assets incorporate knowledge in the production process.

The value added generated by physical capital is broken down into two broad categories: those that do not incorporate knowledge significantly (g assets) and those that do (n-g assets):

$$\sum_{h=1}^{n} K_{hj} * P_{hj}^{K} = \sum_{h=1}^{g} K_{hj} * P_{hj}^{K} + \sum_{h=g+1}^{n} K_{hj} * P_{hj}^{K}$$
[4]

Then, the value of knowledge incorporated through physical assets (*knowledge intensive capital, KIK*) would be given by:

$$KIK_{j} = \sum_{h=g+1}^{n} K_{hj} * P_{hj}^{K}$$
[5]

And the value of knowledge-intensive factors or value added based on knowledge (*knowledge intensive value, KIV*) of activity *j* will therefore be:

$$KIV_{j} = KIL_{j} + KIV_{j}$$
[6]

The relative knowledge intensity (%KIV_j) of activity j is defined as

$$\% KIV_{j} = [KIL_{j} + KIV_{j}]/V_{j}P_{j}^{V}$$
[7]

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Given the knowledge content of each industry, the knowledge intensity of an economy depends on the weight of the various branches in the aggregate. If q industries exist, the knowledge intensity of the economy as a whole (ζ) (*KIV*) is defined as,

$$\% \text{KIV} = \sum_{j=1}^{q} \% \text{KIV}_{j} \left[V_{j} P_{j}^{V} / \sum_{j=1}^{q} V P^{V} \right]$$
[8]

The exercises that will be carried out using LA KLEMS data will adopt the two approaches (the restrictive and the broader one) to measuring the knowledge economy presented in this section. That is, for labor we will consider high- and medium-skilled workers (higher and upper secondary education) as knowledge-intensive and also only high-skilled workers, and for capital, we will compare the results obtained when considering ICT and machinery and equipment capital as knowledge-based assets with those obtained when defining knowledge-based capital as ICT and intangible capital.

3. Statistical data: sources and coverage

The estimates of knowledge intensity following the methodology described previously will be mainly based on data from KLEMS databases: LA KLEMS for the ten Latin-American countries, EU KLEMS for Spain, and USA KLEMS for the United States¹⁴. These databases contain information by industry on variables related to productivity and economic growth: value added, output, employment and skills, gross capital formation by assets and accumulated capital, capital and labor compensation, etc. At the moment, LA KLEMS data is available for the period 1990-2015, whereas EU KLEMS database covers the period 1995–2015. The United States offers similar time coverage for general output magnitudes as well, but the coverage varies depending on the selected variable and its detail. That is why additional sources have been used to supplement the data for this country. Taking all this into account, in this paper we will focus on the period 1995–2015, for which data is available for most of the countries considered.

Thus, the KLEMS databases offer all the variables needed to apply the methodology outlined in section 2: value added, capital compensation, and labor compensation by educational attainment level. However, there are particular problems concerning each variable that need to be solved before the described methodology can be applied.

¹⁴ For the United States, it was necessary to use additional data sources (BEA, BLS,) in order to update and supplement the KLEMS database.

Regarding capital compensation, although previous releases of EU and USA KLEMS included a disaggregation of capital compensation by asset, recent releases include only total compensation by industry. The same is true of LA KLEMS countries. We have therefore to estimate the capital compensation for each asset. This estimation will be made following the KLEMS method (Timmer et al., 2007) and taking as a basis the information on GFCF deflators, capital stock, and depreciation rates included in the KLEMS databases.

With regard to labor-related variables, in the case of EU KLEMS data it is necessary to link up labor input files from different EU KLEMS releases to construct long time series.

Labor data are classified by educational attainment, distinguishing between three levels: high, medium, and low. For our purposes, we have two options: 1) to consider that workers with high- and medium-education levels contribute knowledge to the production process, whereas the rest do not, or 2) to consider that only workers with high-education levels contribute knowledge. In the case of physical capital, the LA KLEMS database distinguishes seven capital assets: three ICT assets and four non-ICT assets (see Table 1). However, the EU, and USA KLEMS databases also include two additional intangible assets (R&D and other intellectual property products) that were included in National Accounts by ESA 2010 but are not yet included in the LA KLEMS database¹⁵. To make the data comparable, these intangible assets have not been considered when calculating knowledge-based GVA for Spain and the United States; only the assets shown in Table 1 are included in the estimation. As stated before, we can either classify ICT assets, transport equipment, and other machinery and equipment as knowledge-based capital assets, whereas residential and non-residential structures are considered to have lower knowledge intensity, or we can consider that only ICT assets are knowledge-intensive, whereas the rest of assets are not.

Thus, we have two measures of knowledge-based GVA, on the one hand, a broader one that includes the remuneration of high- and medium-educated workers and ICT and machinery and equipment capital, and, on the other hand, a restrictive one that only includes the remuneration of high-educated workers and ICT assets.

¹⁵ Among LA KLEMS countries, only Chile and Mexico have already incorporated R&D and other intellectual property products as gross fixed capital formation (GFCF) in their official National Accounts figures.

As explained in section 2, knowledge intensity is measured at the sectoral level. However, the industry classification of the EU and USA KLEMS databases is different from that of LA KLEMS data. While the former have been updated according to the most recent industry classifications (ISIC Rev. 4/NACE Rev. 2), the LA KLEMS database still follows previous classifications (based on ISIC Rev. 3.1/NACE Rev. 1). For that reason, although greater industry detail is available for Spain and the United States, only nine individual industries are considered in this paper, in order to have a common industry classification for all the countries analyzed. Table 2 shows a list of these industries.

Table 1. Capital assets considered for the estimation of knowledge-based GVA

KLEMS assets
ICT assets
Software
Computing equipment
Communication equipment
Non ICT assets
Transport equipment
Machinery & Equipment (excluding ICT)
Non-residential structures
Residential structures

Source: Own elaboration.

Table 2. Industry classification (available for all countries)

Agriculture, forestry, and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale & retail trade; accommodation and food service
Transportation and communications
Financial, real state and business services
Other services

Source: Own elaboration.

Table 3 provides an overview of the two sets of variables involved in the methodology presented in section 2 for Spain, the United States and four Latin-American countries, whose data are already available in the LA KLEMS webpage. Capital and labor inputs are

classified by capital assets and by types of labor according to the level of educational attainment.

Regarding capital input, Table 3 shows the composition of gross fixed capital formation (capital flows) in the countries considered. Because of the variability of this variable, the table shows the average structure for the whole period analyzed (2000–2015). As expected, the share of ICT investment is lowest in the Latin American economies (around 6.5% on average) and in Spain and the United States it is more than twice the Latin American average. The United States has the highest share of ICT assets (18.4%).

In all the countries, residential and non-residential structures are by far the largest category of capital assets, reaching a high of 72.4% in Colombia, 25 percentage points above the country with the lowest share, the United States (47.6%). In general, , real estate assets are more important in the Latin American countries. Machinery and equipment (including transport equipment) accounts for around 30% of total investment in Brazil, Mexico, , Spain, and the United States, whereas its share is 10 percentage points lower in Colombia. The analysis of this structure is important because capital stock stems from the accumulation of GFCF flows. Therefore, the structure of capital stock and capital compensation in each country is determined, at least in part, by GFCF characteristics.

As expected, due to its lower base level, ICT investment has experienced a higher rate of growth than non-ICT assets in all the countries over the period 2000–2015. The difference between the two is especially marked in Chile (10.3 ICT vs. 5% non-ICT) and Spain (5.6% vs. -0.8%). It seems that, in general, ICT investment grows at a higher rate in countries that have lower points of departure in terms of accumulated stock, as is the case of the Latin American countries. The same applies to non-ICT investment. Regarding non-ICT assets, the high growth rate in Colombia (9.7%) is worth noting.

Table 3 also shows information about labor (in terms of total hours worked), according to the level of educational attainment (part 2 of the table). The United States has the lowest share of unskilled labor. In general, the labor structure in this country, and also in Spain, is based more on educated labor. Among LA KLEMS countries, only Chile shows a similar structure, with higher shares for high-skilled than for low-skilled workers. The structure of labor differs among countries and these differences will play an important role in determining the intensity of the use of knowledge in the economy. The general pattern since 2000 has been, as expected, a decrease in the share of the lower levels in favor of the other two. However, whereas in the United States and Spain the proportion of less qualified labor has decreased in terms of hours worked, in Chile, Colombia, and Mexico the hours worked by this group have increased. In the majority of countries, in general, job creation is concentrated among workers with higher educational levels, who, according to the described methodology, are the main contributors to knowledge.

Table 3. Descriptive statistics

a) GFCF structure by assets, 2015* (%) USA Brazil Chile Colombia Mexico Spain ICT 18.41 6.07 8.00 7.06 4.27 15.10 Software 12.16 2.47 3.70 0.87 0.16 7.83 Computing equipment 2.85 1.13 2.15 1.72 2.46 1.64 Communication equipment 3.40 2.47 2.15 4.56 2.39 4.81 Non ICT 81.59 93.93 92.00 92.94 95.73 84.90 Transport equipment 10.61 11.59 8.91 8.71 11.45 -Machinery & Equipment (exclu. ICT) 23.37 22.12 25.12 11.59 25.48 18.69 Non residential structures 32.29 46.58 32.01 26.17 43.99 30.12 **Residential structures** 21.44 27.93 22.90 25.86 29.54 24.63 Total 100.00 100.00 100.00 100.00 100.00 100.00

a) Gross fixed capital formation

b) GFCF. Average annual growth rates (2000-2015*)	USA	Brazil	Chile	Colombia	Mexico	Spain
ІСТ	3.92	6.63	10.30	10.85	4.94	5.64
Software	4.11	7.76	14.30	13.58	3.99	5.02
Computing equipment	5.84	7.63	8.06	14.25	4.10	6.53
Communication equipment	2.09	4.09	7.78	9.52	5.29	6.09
Non ICT	0.30	4.41	4.98	9.74	2.18	-0.81
Transport equipment	2.98	7.91	-	11.98	4.18	1.42
Machinery & Equipment (exclu. ICT)	1.90	5.19	7.74	11.27	4.25	0.22
Non residential structures	-0.88	3.70	5.04	8.39	0.40	-0.65
Residential structures	-0.85	3.18	1.48	11.35	1.82	-2.19
Total	0.89	4.65	5.36	9.26	2.31	-0.14

Table 3. Descriptive statistics (cont.)

b) Labor

a) Labor share by level of education, 2015 (%)	USA	Brazil	Chile	Colombia	Mexico	Spain
High	37.95	18.41	35.20	21.73	13.45	40.74
Medium	54.24	42.48	45.93	42.34	46.54	24.00
Low	7.81	39.12	18.87	35.93	40.01	35.26
Total	100.00	100.00	100.00	100.00	100.00	100.00

b) Labor. Average annual growth rates (2000-2015)	USA	Brazil	Chile	Colombia	Mexico	Spain
High	2.11	6.78	4.25	5.92	1.03	3.32
Medium	-0.46	3.13	0.24	3.38	2.54	1.84
Low	-1.61	-0.74	1.54	1.57	0.20	-2.34
Total	0.30	1.75	1.64	3.10	1.31	0.48

* 2013 for Brazil and 2014 for Colombia.

Note: In the case of Chile, Transport equipment is included in Machinery & Equipment (exclu. ICT). Source: BEA, BLS, EU KLEMS (2018), LA KLEMS (2018), World KLEMS and own elaboration.

4. Knowledge intensity estimates. Aggregated results

This section presents the main aggregated results that can be obtained with the exercises proposed in section 2 for measuring the knowledge economy. In order to do that, some preliminary results from Mas, Hofman and Benages (2019) are used. Our objective is to replicate these estimations (which correspond to the broader approach described in section 2) but including LA KLEMS data which is still to be published and to compare them with the results that will be obtained when applying the restrictive approach described in section 2.

The first result is the knowledge economy's share of total GVA (as given by Equation [8]) for each individual country during the period considered. Preliminary results gathered in Mas, Hofman and Benages (2019) are shown in Figure 1. Panel a shows the profiles followed by the six American countries analyzed in that paper (including four Latin American countries that we will also include in our analysis: Brazil, Chile, Colombia and Mexico) and the right-hand panel shows the same information for five European countries, namely France, Germany, Italy, Spain and United Kingdom. The period for which the information is available in Mas, Hofman and Benages (2019) is 2000-2015.





Within the American countries, as expected, the United States and Canada have the highest shares, slightly higher in the United States than in Canada. However, both of them show a declining trend over the period. On average, for the whole period 2000–2015, in the North American countries the knowledge economy accounted for around 73% of total GVA. This figure contrasts with the share of the knowledge economy in the four Latin American countries considered. Chile has by far the highest share, averaging around 63%, but with a very volatile profile. From the start of the great recession the share of the knowledge economy in Chile increased and by the end of the period was approaching the level of the United States and Canada (if we exclude the slight decline in 2015). Of the other three Latin American countries, Brazil used to be the one with the highest share, but its position worsened from 2008 onwards. Mexico follows, with a share close to 55% and a rising profile, while the knowledge economy's share of total GVA was lowest in Colombia, which also shows only a weak tendency towards improvement.

Of the five European countries (Figure 1, panel b), Germany leads, outperforming even the United States, with a knowledge economy that accounts for close to 80% of total GVA and a stable or even slightly increasing tendency. The other four countries have

Source: Mas, Hofman and Benages (2019)

lower shares than the two North American countries and are clustered in two groups. France and the United Kingdom share a common pattern, showing a positive trend and with shares close to 70–75% by the end of the period. Italy and Spain form the second cluster, with the knowledge economy likewise increasing its share of GVA, approaching a lower value of around 60% by the end of the period. It will be interesting to assess the advance of the knowledge-based economy in the remaining Latin American countries whose data release is pending and to compare it with the results obtained with the restrictive approach.

Figure 2 summarizes the position of the 11 countries, at the beginning and at the end of the period, in terms of the knowledge economy's share of total GVA. The following comments are in order. At the beginning of the period the two North American countries and Germany had the highest share, with the United States taking the lead. France and the United Kingdom followed. Already in 2000 Chile held sixth place in the ranking, ahead of Italy and Spain, which ranked last among the five European countries. The last places were taken by Brazil, Mexico, and Colombia. In that year, the distance between the leader, the United States, and the country at the bottom of the ranking, Colombia, reached 35 percentage points.

Figure 2. Knowledge-based GVA. International comparison, 2000 and 2015 (percentage over total GVA)



Note: Countries are ranked according to Knowledge GVA share in 2015. 2013 is the last available year in the case of Brazil and 2014 in the case of Colombia, Canada and Italy.

Source: Mas, Hofman and Benages (2019)

Fifteen years later, in 2015, Germany was the leader, having overtaken the United States, while France had surpassed Canada, which was relegated to fourth position. The UK had dropped one place, from fourth to fifth, and Chile ranked sixth. Spain and Italy followed, but with Spain overtaking Italy, which slipped into eighth position. Mexico, Brazil, and Colombia still ranked at the bottom, but with Mexico slightly outperforming Brazil. An interesting point is that the two North American countries are the only ones to have seen a decline in the knowledge economy's share of GVA over the period. In 2015 the distance between the leader (Germany) and the country at the bottom (still Colombia) was slightly smaller than in 2000, at 32 percentage points.

Figure 3 shows the dynamics of knowledge-based GVA, measured in real terms, over the 2000–2015 period in the 11 countries considered in Mas, Hofman and Benages (2019). The four Latin American countries show the fastest growth, with Colombia and Chile taking the lead, followed by Brazil and Mexico (panel a). Canada and especially the United States followed a slower path than either the four Latin American countries or Spain, which was the most dynamic of the European countries (panel b). Even the United Kingdom and France had higher rates of growth than the United States over the period. The most sluggish growth rates are those of Germany and especially Italy, which had the slowest growth of all the 11 countries. Overall, Figure 3 confirms that there was some convergence over the period, with the countries ranked lowest in 2000 growing faster than the leaders. Italy is the only exception to this general convergence behavior.

The information provided by Figure 4 qualifies the above conclusions. It shows the dynamics of non-knowledge GVA, also in real terms. The first thing that draws attention when comparing this information with that provided by Figure 3 is the much more dynamic behavior of the American countries (panel a), compared to the European ones (panel b), whose profile is almost flat or, in the case of Italy, even declining. In contrast, panel a) shows the dynamic behavior of the American countries, with Colombia, Brazil, and Chile in the lead (as with the knowledge economy in Figure 3), although even the United States and Canada show faster growth in the non-knowledge than in the knowledge economy.





a) American countries

b) European countries

Source: Mas, Hofman and Benages (2019)





b) European countries



Source: Mas, Hofman and Benages (2019)

Overall, the picture given by the two figures is of less dynamic European countries, especially in non-knowledge-based GVA, in contrast to very dynamic Latin American countries. The United States and to a lesser extent Canada show a more dynamic behavior than the European countries, especially in the non-knowledge economy.

A complementary way of observing the same phenomenon is provided by Figure 5, which depicts the annual rates of growth of knowledge and non-knowledge GVA over the period 2000–2015. The four Latin American countries take first place in both aggregations and the rate of growth of the knowledge economy is higher than that of the non-knowledge economy in all cases. Canada and the United States experienced fairly high rates of growth for both components, but higher in the non-knowledge than in the knowledge part of the economy, especially in the case of the United States. The opposite is true of the European countries. Spain, France, and Italy experienced either nil, or negative, rates of growth of the non-knowledge economy, while the United Kingdom and Germany had positive growth in non-knowledge GVA but still lower than the growth in knowledge-based GVA.





* 2000-2013 for Brazil, 2000-2014 for Canada, Colombia and Italy Note: Countries are ranked according to knowledge GVA growth. Source: Mas, Hofman and Benages (2019)

Figures 3, 4, and 5 provide the rates of growth of knowledge and non-knowledge-based GVA considered individually. Figure 6 combines this information with each component's share of total GVA, showing each one's contribution to total GVA growth. This information is provided for the whole period 2000–2015 (panel a) and also separately for the pre-recession (panel b) and post-recession (panel c) years.

Regardless of the period analyzed, Colombia, Chile, and Brazil have the highest rates of GVA growth and also the highest contribution of the knowledge economy (in percentage points). Mexico shows more modest results, especially when compared with the other three Latin American countries. The United States and Canada stand in the middle range, both in growth rates and in the contribution of the knowledge economy. However, their behavior was more positive in the expansion years (2000–2007) than in the years that followed. The five European countries show a more contrasting trajectory. For the whole 2000–2017 period, the rate of GVA growth was similar in France, Germany, Spain, and the United Kingdom, and in all cases the (almost) only source of that growth was the knowledge-based economy. Italy is the exception, presenting the lowest rate of GVA growth, together with a negative contribution of the non-knowledge economy.

There is a sharp contrast in the behavior of the five European countries between the pre- and post-recession years. During the expansion years (panel b), the knowledge economy made an important contribution to growth in all of them. The consequences of the great recession after 2007 (panel c) were dramatic for the European countries, especially for Spain and Italy, which presented a negative average annual rate of growth for the whole 2007–2015 period. And all five countries had negative contributions of the non-knowledge economy throughout those years, indicating that the non-knowledge part of the economy is more vulnerable to difficult times than its knowledge counterpart.

To finish the presentation of preliminary results, Figure 7 shows knowledge-based GVA per capita (expressed in 2010 US dollars PPP per person) at the beginning and end of the period. The two North American countries lead the ranking, with the United States in first place. They are followed by the five European countries in this order: Germany, France, the United Kingdom, Italy, and Spain. The four Latin American countries present lower values, with Chile ranking highest in this group, followed by Mexico, Brazil, and Colombia. However, it is worth noting that all 11 countries experienced an improvement in this variable between 2000 and 2015.







a) 2000-2015*









*2000-2013 for Brazil, 2000-2014 for Colombia, Canada and Italy. **2007-2013 for Brazil, 2007-2014 for Colombia, Canada and Italy. Source: Mas, Hofman and Benages (2019)

Figure 7. Knowledge-based GVA per capita, 2000 and 2015* (2010 US Dollars PPP per person)



* 2013 for Brazil and 2014 for Colombia, Canada and Italy. Source: Mas, Hofman and Benages (2019)

Despite the positive performance of the knowledge-based economy in all the countries and the strong growth trend shown by the less developed ones (namely the Latin American countries), the convergence between them is only moderate, as can be observed in Figure 8, which shows the coefficient of variation for knowledge, nonknowledge, and total GVA per capita, considering all the countries analyzed. There is only a slight convergence in knowledge-based GVA per capita and a somewhat stronger convergence in non-knowledge GVA per capita.

Taking as a point of departure these aggregated results, our contribution aims at deepening the characterization of the knowledge-based economy in Latin American countries and examining the evolution of the determinants of the knowledge intensity (capital and labor) in these countries over the years. To this end some additional analysis are proposed hereafter:

Figure 8. Convergence in the knowledge and non-knowledge based GVA per capita among countries. International comparison, 2000-2013 (coefficient of variation)



- Disaggregation of knowledge-based GVA by source

As already explained in section 2, our approach to the knowledge-based economy assumes that knowledge is embedded in the two factors of production —labor and capital— and that the contribution of each individual asset is determined by the prices of the services it provides. Thus, it will be useful to analyze the knowledge and non-knowledge compensation, as a percentage of GVA, of all the components considered (in addition to knowledge and non-knowledge capital and labor, also distinguishing between ICT and non-ICT knowledge-based capital and between high and medium-skilled knowledge-intensive labor.

According to Table 3, it is expected that the Latin American countries account for the relatively higher weight of *Non-knowledge-intensive capital* and the relatively lower weight of medium- and high-skilled labor. However, it will be interesting to try to find some common patterns among Latin American countries.

Also the annual rates of growth for each of the components of capital and labor will be analyzed, in order to determine which countries have the highest rates of growth. The contribution of knowledge and non-knowledge compensation (and their components) to total GVA growth will also be calculated.

According to the results found in Mas, Hofman and Benages (2019), in almost all the countries analyzed, the contribution of *Knowledge-intensive labor* to total GVA growth was higher than the contribution of Knowledge-intensive capital. Within Knowledgeintensive labor, in most of the countries (the exceptions being Mexico, Germany, and Italy) the contribution from high-skilled workers was larger than that from mediumskilled workers. The contribution of Knowledge-intensive capital has been negative in three of the European countries, namely, France, the United Kingdom, and Italy. In the case of France and the United Kingdom, this was due to the Other knowledge-intensive capital component (machinery and equipment, basically), while in Italy both components of knowledge-intensive capital (machinery and equipment and also ICT capital) had a negative contribution. Germany and Brazil were the other two countries with a negative ICT capital contribution, although offset by the growth of machinery and equipment capital. In the remaining eight countries considered in Mas, Hofman and Benages (2019) the ICT capital contribution was positive. In a set of countries the contribution of Non-knowledge-intensive capital was higher than its Knowledgeintensive counterpart. However, in none of the countries, without exception, was the contribution of Non-knowledge-intensive labor higher than its Knowledge-intensive counterpart. In fact, in the majority of countries the contribution of Non-knowledgeintensive labor to GVA growth was negative. The exceptions were three Latin American countries (Brazil, Chile, and Colombia), where it was positive.

- Disaggregation of knowledge-based GVA by industry

A distinctive characteristic of the KLEMS methodology is the emphasis it puts on the importance of industry disaggregation. In fact, the results outlined until now come from the aggregation of industry data, as described in section 2 (see Equation [8]). Thus, it is worth analyzing the results regarding knowledge-based GVA and its composition from a sectoral perspective.

This perspective has already been addressed in Pérez and Benages (2012), Mas, Hofman and Benages (2018 and 2019), although without going very far into detail. In this paper,

we propose to study the composition of the GVA generated by each branch according to its knowledge content, its evolution over the years, its contribution to total knowledge-based GVA and the trend observed in each industry in terms of knowledge intensity. Also the convergence among countries will be analyzed.

Related with sectoral results, we propose also a decomposition of knowledge-based economy growth, in order to determine the levers of growth. A shift-share analysis is proposed to this end.

Shift-share analysis is widely used to decompose the changes in an aggregate variable over time into three components: within-industry effect, sectoral static effect, and sectoral dynamic effect. It thus allows us to explain the changes in the knowledge intensity of GVA (Y^{K}/Y) over a specific period of time (0 to T) as follows:



where $\frac{Y_T^K}{Y_T} - \frac{Y_0^K}{Y_0}$ is the change in knowledge intensity between years 0 and *T*, *j* is the industry, and θ_{iT} is the share of GVA in industry *j* in year *T*.

The within-industry effect shows the growth of knowledge intensity that would have occurred even without any structural change, i.e., due to the aggregate knowledge intensity gains (positive sign) or losses (negative sign) arising from internal improvements in knowledge intensity within each industry. The sectoral effect captures the consequences of the re-allocation of factors between sectors towards industries with a higher initial level of knowledge intensity (static effect) or with a higher rate of knowledge intensity growth (dynamic effect).

A similar exercise has been carried out in Mas, Hofman and Benages (2019). The main results can be summarized as follows. First, the within-industry effect is by far the most important determinant of the knowledge intensity variation in all countries, especially in Chile, Colombia, Mexico, France, and Spain. Second, the sectoral effect had a negative impact in all the countries, with the sole exception of Spain. These results show that the change in the sectoral composition of GVA during the years considered did not contribute to the growth of knowledge-based GVA, except in the case of Spain.

6. Conclusions

The proposed metric calculates the knowledge content of an economy based on more accurate and disaggregated measurements of human and physical capital services by branch of activity. To compute the size and composition of the knowledge economy, we use two definitions of knowledge-based inputs: a broader one and a more restrictive one. The first includes ICT and machinery and equipment assets as capital inputs and the highest and medium levels of educational attainment as labor inputs and the latter includes only ICT assets as knowledge-based capital and higher levels of educational attainment as knowledge-intensive labor. Once the knowledge-based inputs have been identified following both approaches, we quantify the portion of income which remunerates the services that these factors provide (capital and labor compensation, in KLEMS terminology) and, by extension, their contribution to GVA. This paper will analyze the behavior followed by ten Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, El Salvador, Honduras, Mexico, Peru and Dominican Republic), Spain and Mexico. The period covered will be 1995 to 2015, which is the latest year available for all the countries. The information comes from the most updated releases of EU KLEMS, LA KLEMS, and the KLEMS database for the United States.

The conclusions that can be drawn from the proposed exercises could be very useful--from the perspective of designing public policies aimed at improving an economy's knowledge intensity and its growth. New policies could be defined to facilitate the penetration of knowledge-intensive assets (both capital and labor) in Latin American economic sectors, especially those with lower knowledge-intensity. The comparison with the United States and Spain, as benchmarks, is also valuable as it offers two reference points to look at.

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